(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 June 2001 (14.06.2001)

PCT

(10) International Publication Number
WO 01/43449 A1

(51) International Patent Classification[7]: H04N 13/04, 13/00

(21) International Application Number: PCT/US00/30683

(22) International Filing Date:
8 November 2000 (08.11.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/456,826 8 December 1999 (08.12.1999) US

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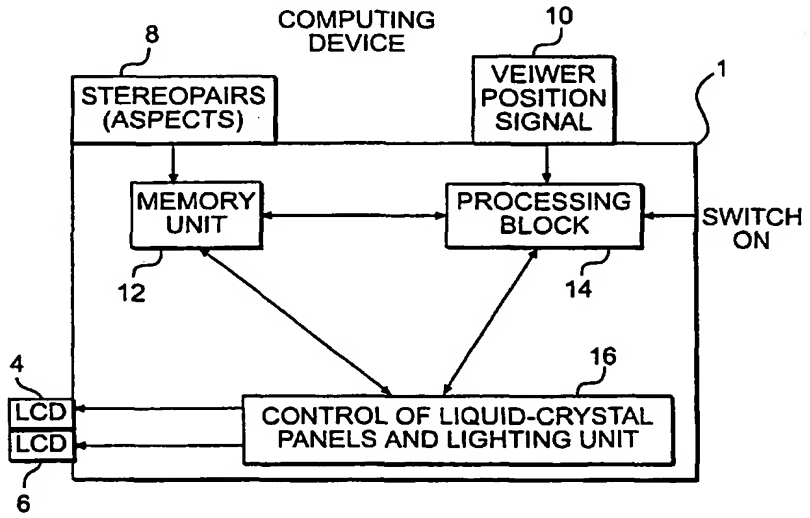
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*
— *With amended claims.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: VOLUMETRIC DISPLAY DEVICE



(57) Abstract: A system and method of the display and viewing of multi-aspect imagery. Viewer position is determined as used as a basis for the staging and display of multi-aspect (stereo) imagery. Through use of three LCD panels, a distant panel having luminous radiation corresponding to portions of a multi-aspect image, and medium-distant, and near LCD panels which are transmissive and which are all regulated by a processor, those aspects of the image pair corresponding to the view of the left and right eye of the viewer can be seen. When the total light energy for a given cell of the LCD panels exceeds a certain threshold an error figure is calculated. When the error exceeds a certain error threshold, the luminous radiation of the distant panel is adjusted and/or a new image is staged.

WO 01/43449 A1

VOLUMETRIC DISPLAY DEVICE

Field of the Invention

This invention relates generally to a stereoscopic display of images and related apparatus. More specifically, the present invention is a system and method for 3-D visualization based on parallel information processing of stereo imaging on multi aspect displays.

Background of the Invention

Stereoscopic display of images has become increasingly important in modern times. For example, training of professionals from pilots to physicians now frequently relies upon the visualization of stereographic images. Further, it is important that multiple aspects of an image be able to be viewed so that, for example, during simulations of examination of human or mechanical parts, a viewer can have a continuous stereoscopic view of those parts without having to change data or switch images.

Conventional stereoscopic display systems have been in use for many years. All of these rely upon segregating images for the right and left eyes. For example, an apparatus which sequentially displays different views to the left and right eye of a viewer has been used successfully in cartographic and other applications. In this instance, using stereo image alternation, a different view is sequentially presented to the left and right eye of the viewer. This is also accomplished by using cathode ray tubes or liquid crystal displays whereby a viewer wears special glasses such as polarizing glasses or liquid crystal shutter glasses in order to see a different image in the left and right eye.

Lenticular lenses have also been used to allow a viewer to see a left and right image separately when a viewer is at an optimum distance from the lenticular lens screen. For example Patent Number 5,838,494 to Araki was issued for an "Apparatus for Displaying Image Allowing Observer to Recognize Stereoscopic Image." This apparatus uses a lenticular screen displaying a

plurality of striped images each stripe corresponding to the parallax view of the left and right eye when the user is looking through the lenticular screen. This apparatus presents a limited number of views of a stereo image pair and is therefore limited in the number of views that can be displayed.

Patent Number 5,930,037 was issued to Imai for a "Stereoscopic Display Apparatus Which Prevents Inverse Stereoscopic Vision." This invention relates to the use of lenticular lenses to see stereoscopic image but also prevents the phenomenon known as inverse stereoscopic viewing when the right eye sees the image that is destine for the left eye and vice versa. While this does prevent a certain phenomena from occurring, this invention is limited in the number of stereoscopic image pairs that can be present to a particular user.

Patent Number 5,712,732 was issued to Street for an "Auto Stereoscopic Image Display Adjustable for Observer Location and Distance." This invention was created to account for the fact that, when a lenticular lens is used, a viewer must be at a particular distance from the lens in order for the lens to operate correctly. This invention comprises a distance measuring apparatus allowing a system to determine the position of the viewer's head in terms of distance and position (left-right) relative to the screen. In this fashion an appropriate stereo graphic image pair can be presented to the user at any particular location. Again this invention relies upon a lenticular screen to separate the parallax views for the left and right eye of the viewer. The head location apparatus dictates various other geometries associated with viewing the stereo graphic pairs of an image. However, this invention relates to adapting for the location of the viewer's head during such viewing and is limited in the number of aspects of images that can be created.

What would be desirable is a system that provides numerous aspects or "multi aspect" display such that the user can see many aspects of a particular object when desired. It would further be useful for such viewing to take place in a flexible way so that the viewer is not constrained in terms of the location of the viewer's head when seeing the stereo image.

Summary of the Invention

It is therefore an objective of the present invention to provide for multi aspect image viewing to created a stereo image.

It is a further objective of the present invention to be able to present an unlimited number of aspects of an image to a viewer so as not to lose any information while simultaneously having a full stereo image presented to the viewer.

It is yet another objective of the present invention to simplify the 3-D visualization of objects.

It is a further objective of the present invention to improve the perception of three dimensional information to a viewer.

It is a further objective of the present invention to remove sources of error from the viewing of stereo graphic images. It is yet another objective of the present invention to eliminate any mask or obstruction from the view of a viewer when reviewing stereo imagery.

It is yet another objective of the present invention to eliminate the parallax barrier from the view of viewers trying to visualize a three dimensional scene. In conventional parallax barrier type of lenticular lenses, very few aspects of a particular object are presented. Further, one screen, or plane, contains all of the information about the various aspects while the other screen (or mask) contains only the lenticular lens or running slit that isolates the left aspect from the right aspect of an image being viewed. Further, whenever a viewer uses a parallax barrier type of viewing system, the viewer is actually seeing the parallax barrier or the lenticular lens. This further limits the number of aspects of an image that can be seen by a viewer in attempting to view stereo graphic images.

The present invention is a system and method for three dimensional visualization based upon parallel information processing of stereo and multi aspect images. Further the processing is adaptive in nature so as to be continually processed as the location of the viewer changes. Thus the perception of 3 dimensional images by the viewer is improved by not constraining the viewer

in any meaningful way.

In the present invention, at least two LCD screens are positioned one behind an other. Each such screen is composed of multiple cells which collectively are capable of forming an image. The screens are transmissive, i.e. they both transmit light. An illumination means is positioned behind the screens to illuminate the LCD images created.

Each screen presents an aspect of the stereo image being viewed. The information is derived from the database of stereo pairs, or aspects, stored in a memory unit. A memory unit provides a stereo pair to the processing block which in turn controls the liquid crystal displays each of which displays an aspect of the image being viewed. Further the processing block controls the lighting unit which illuminates the liquid crystal displays.

Since each LCD contains all of the information about a particular aspect or view of the image in question, there is no loss of resolution such as that which occurs when both aspects must be displayed on a single screen or plane as with lenticular viewing systems.

The image, or corresponding pair of aspects, are presented to the viewer based upon a sensing of the viewer position. This viewer position signal is input to the processing block by means known in the art such as IR sensing of position or RF or ultrasonic tracking means which in turn retrieves a different stereo pair from the memory unit for subsequent presentation and display by the controller of the liquid crystal panels.

An image that is to be presented to a particular viewer is preliminarily processed and serves as a mask. Thus the viewer sees no images other than the object it self. This, in contrast to conventional parallax barrier type imaging systems where the mask can clearly be seen. In addition, this preliminary processing of the image results in the absence of noise and distortion of a visual nature such as that that this created by lenticular screens or lenses.

A Brief Description of the Drawings

Figure 1 illustrates the display system.

Figure 2 illustrates the computational and control architecture of the present invention.

Figure 3 illustrates the light beam movement of the present invention.

Figure 4 illustrates the data flow for the operation of the display control program.

As noted above, the present invention is a system and method for presentation of multiple aspects of an image to create a three dimensional viewing experience using two liquid crystal panels.

Referring to Figure 1, computational device **1** provides control for an illumination subsystem **2** and for the display of images on two discreet liquid crystal displays **4** and **6.** Illumination source **2** which is controlled by the computational device **1** illuminates the transmissive liquid crystal displays **4** and **6** which are displaying images provided to them by the computational device **1**.

Referring to Figure 2, for the detail on computational device **1** is illustrated. The invention comprises a data base of stereo pairs or aspects **8** which are provided to the memory unit **12**. Memory unit **12** has several functions. Initially memory unit **12** will extract and stage a particular stereo pair from the stereo pair data base **8**. This stereo pair will correspond to an initial viewing position. As noted above a viewer position sensor **10** provides a viewer position signal to processing block **14**.

All during the viewing session, the viewer position signal **10** is constantly monitored and provided to processing block **14**. Depending upon the viewer position and subsequent error processing as noted (below) information from processing block **14** regarding viewer position **10** is provided to memory unit **12** for subsequent extraction of the stereo pair aspects from the data base **8**. Thus the present invention is constantly providing an updated series of stereo pairs based upon the viewer position **10**.

Memory unit **12** provides the stereo pair to the liquid crystal control panel and lighting unit **16**. LCD control and lighting unit **16** provides the left and right images to the appropriate LCD panels **4, 6** as well as controls the lighting that

illuminates the transmissive LCD panels **4, 6**. Processing block **14** also provides instruction to LCD and lighting control unit **16** to provide the appropriate illumination as well as display of the stereo pairs.

It should be noted that memory unit **12** holds the accumulated signals of individual cells or elements of the liquid crystal display. Thus the memory unit **12** has the ability to accumulate and analyze the light that is traveling through relevant screen elements of the LCD screens toward the right and left eyes of the viewer which are identified by the processing block **14** based upon the viewer position signal **10**.

Referring to Figure 3 the diagram of the light beam movement of the present invention is illustrated. In this illustration a three panel liquid crystal display is illustrated. In this instance the display comprises an image presented on a near panel **18**, a medium-distant panel **20** and a distant image panel **22**. The relative position of these panels is known and input to the processing block for subsequent display of images.

Different portions of different aspects or each stereo pair are displayed in each element of panels **18, 20**, and **22**. In this illustration left eye **36** sees a portion **28** on panel **18** of an image. Since the panels are transmissive in nature, left eye **36** also sees a portion of one aspect of an image **26** on the medium distant LCD panel **20**. Additionally, and again due to the transmissivity of each LCD panel, left eye **36** also sees a portion of one aspect **24** of an image which is displayed on a distant LCD panel **22**. In this manner the portions of the image are those that are to be seen by the left eye of the viewer

Similarly, right eye **34** sees the same portion **28** of an aspect of an image on the near panel **18**, as well as sees a portion of an aspect **30** of an image displayed on the medium distant panel **20** as well as a portion of an aspect **32** of an image on distant panel **22**. These portions of the image are those that are to be seen by the right eye of the viewer.

These portions of aspects and mask seen by the right and left eye of the viewer constitute two views seen by the viewer thereby creating a stereo image.

Referring to Figure 4, the data flow for the manipulation of the images of the present invention is illustrated. As noted earlier the memory unit **12** processing block **14** and LCD control and luminous control **16** regulate the luminous radiation emanating from the far screen **22** and the transmissivity of the medium distant screens **20** and **18**.

Information concerning two discreet two dimensional images (two aspects) of an object each of which is depicted in multiple different areas on the LCD screens and information about positions of the right and left eyes of the viewer are adjusted by the processor block **14**.

Signals corresponding to the transmission of a portion **28** of near screen **18**, the transmissivity of medium-distant **20** corresponding to the left and right eye respectively (**26**, **30**) and the far screen **22** corresponding to the luminous radiation of those portions of the image of the left and right eye respectively (**24**, **32**) are input to the processing block following the set program.

The light signals from the cells of all screens which are directed toward the right and left eye of each viewer are then identified. In this example signals from cell **28**, **26**, and **24**, are all directed toward the left eye of the viewer **36** and signals from block **28**, **30**, and **32** are directed the right eye of the viewer **34**.

Each of these left and right eye signals are summed **38** to create a value for the right eye **42** and the left eye **40**. These signals are then compared in a compare operation **48** to the relevant parts of the image of each aspect and to the relevant areas of the image of the object aspects **44** and **46**.

Keeping in mind that the signal is important a function of the location of the viewer's eyes, the detected signal can vary to some extent. Any errors from the comparison are identified for each cell of each near mask, and distant screen. Each error is then compared to the set threshold signal and, if the error signal exceeds the set threshold signal, the processing block control changes the signals corresponding to the luminous radiation of at least part of the distant screen **22** cells as well changes the transmissivity of at least part of the medium-distant and near cells of the LCD displays.

If the information concerning discreet two dimensional images of two aspects of the object changes, as a result of movement of the viewer position, the processing block senses that movement and inputs into the memory unit signals corresponding to luminous radiation of the distant screen cells as well as the transmissiveness of the medium-distant and near screen cells until the information is modified. When the viewer position varies far enough to require a new view, that view or image is extracted from the database and staged to the LCD screens.

It should also be noted that the system of the present invention can be used with multiple viewers observing imagery simultaneously. The system simply recognizes the individual viewers' positions and stages images appropriate for the multiple viewers.

A system and method for the viewing of stereo imagery has now been shown. It will be apparent to those skilled in the art that other embodiments of the present invention are possible without departing from the scope of the invention as disclosed.

I claim:

1. A system for visualization of multi-aspect images comprising:
a viewer position signal generator (VPSG);
a processor connected to the VPSG and adapted to receive a viewer position signal indicative of the position of the viewer's eyes;
a memory unit connected to the processor for receiving instructions from the processor for staging of stereopairs of images;
a liquid crystal display (LCD) panel and lighting controller connected to the processor and to the memory unit for receiving the staged stereopairs of images and for receiveing instructions from the processor; and
at least two LCD display panels, each comprising cells, for displaying sections of the stereopairs of images on each panel, the LCD panels arranged one behind the other, and at least one of the LCD panels nearest the viewer being transmissive, and wherein each LCD panel displays part of each of the images of the stereopair of images.

2. The system for visualization of multi aspect images of claim 1 wherein the at least two LCD panels further comprise a near, medium distant and distant LCD panel; and
wherein the memory unit, processor and LCD and lighting controller regulate the luminous radiation of the distant LCD panel, and the transmissivity of the medium-distant and near LCD panels.

3. The system for visualization of multi aspect images of claim 2 wherein signals corresponding to the luminous radiation of at least part of the distant LCD panel and the transmissivity of the medium-distant and near LCD panels are input to the memory unit by the processor; and
wherein the processor further comprises instructions for identifying the

amount of light directed from the cells of the near, medium distant and distant LCD panels to the right and left eyes of a viewer; and wherein the processor further comprises instructions for comparing the amount of light detected from the cells of the near, medium distant , and distant LCD panels to a set threshold signal.

4. The system for visualization of multi-aspect images of claim 3 wherein the processor further comprises instructions for calculating an error amount based upon the difference between the set threshold signal and the amount of light reaching the right and left eyes of the viewer; and the processor further comprising instructions for modifying the luminous radiation for at least part of the distant LCD panel, and the transmissivity of the medium-distant and neat LCD panels if the error amount exceed an error signal threshold.

5. A method for viewing multi-aspect imagery comprising:
sensing and creating a signal for the position of at least one viewer's eyes;
inputting the viewer position signal to a processor;
staging steropairs of images to at least two LCD panels based upon the view position signal from a database of multi-aspect images; and
displaying part of each steropair of images on the LCD panels corresponding to the right and left eyes of the viewer.

6. The method of viewing multi-aspect imagery of claim 5 wherein the staging of stereopairs of images further comprises staging the stereopairs of images to a near, medium-distant and distant LCD panel; and regulating the luminious radiation of the distant panel, and the transmissivity of the medium-distant and near LCD panels.

7. The method of viewing multi-aspect imagery of claim 6 further comprising:
Inputting to a memory unit the signals corresponding to the luminous

radiation of at least part of the distant LCD panel and the transmissivity of a corresponding part of the medium-distant and near LCD panels; and

comparing the amount of light to a set threshold .

8. The method of viewing multi-aspect imagery of claim 7 further comprising:

calculating an error amount from the difference between the amount of light and the set threshold; and

modifying the luminous radiation for at least part of the distant LCD panel if the error amount exceeds and error threshold.

AMENDED CLAIMS

[received by the International Bureau on 12 March 2001 (12.03.01);
original claims 1,5 and 6 amended;
remaining claims unchanged (2 pages)]

1. A system for visualization of multi-aspect images comprising:
a viewer position signal generator (VPSG);
a processor connected to the VPSG and adapted to receive a viewer position signal indicative of the position of the viewer's eyes;
a memory unit connected to the processor for receiving instructions from the processor for staging of stereopairs of images;
a liquid crystal display (LCD) panel and lighting controller connected to the processor and to the memory unit for receiving the staged stereopairs of images and for receiving instructions from the processor; and
at least two LCD display panels, each comprising cells, for displaying sections of the stereopairs of images on each panel, the LCD panels arranged one behind the other, and at least one of the LCD panels nearest the viewer being transmissive, and wherein each LCD panel displays part of each of the images of the stereopair of images without any polarizing elements separate from said LCD display panels.

2. The system for visualization of multi aspect images of claim 1 wherein the at least two LCD panels further comprise a near, medium distant and distant LCD panel; and
wherein the memory unit, processor and LCD and lighting controller regulate the luminous radiation of the distant LCD panel, and the transmissivity of the medium-distant and near LCD panels.

3. The system for visualization of multi aspect images of claim 2 wherein signals corresponding to the luminous radiation of at least part of the distant LCD panel and the transmissivity of the medium-distant and near LCD panels are input to the memory unit by the processor; and

wherein the processor further comprises instructions for identifying the amount of light directed from the cells of the near, medium distant and distant LCD panels to the right and left eyes of a viewer; and
wherein the processor further comprises instructions for comparing the amount of light detected from the cells of the near, medium distant , and distant LCD panels to a set threshold signal.

4. The system for visualization of multi-aspect images of claim 3 wherein the processor further comprises instructions for calculating an error amount based upon the difference between the set threshold signal and the amount of light reaching the right and left eyes of the viewer; and
the processor further comprising instructions for modifying the luminous radiation for at least part of the distant LCD panel, and the transmissivity of the medium-distant and neat LCD panels if the error amount exceed an error signal threshold.

5. A method for viewing multi-aspect imagery comprising:
sensing and creating a signal for the position of at least one viewer's eyes;
inputting the viewer position signal to a processor;
staging steropairs of images to at least two LCD panels based upon the view position signal from a database of multi-aspect images; and
displaying part of each steropair of images on the LCD panels corresponding to the right and left eyes of the viewer without using any polarizing elements separate from said LCD display panels.

6. The method of viewing multi-aspect imagery of claim 5 wherein the staging of stereopairs of images further comprises staging the stereopairs of images to a near, medium-distant and distant LCD panel; and
regulating the luminous radiation of the distant panel, and the transmissivity of the medium-distant and near LCD panels.

Statement under Article 19(1)

By the present amendment, claim 1 has been amended to correct the spelling of "receiving" and define the system as "without any polarizing elements separate from said LCD display panels;" claim 5 has been amended to define the method "without using any polarizing elements separate from said LCD display panels;" and claim 6 has been amended to correct the spelling of "luminous." All the remaining claims are unchanged.

The display of U.S. 5,973,831 uses polarizing elements separate from any LCD display panels.

1/4

NEUROSTEREODISPLAY SYSTEM

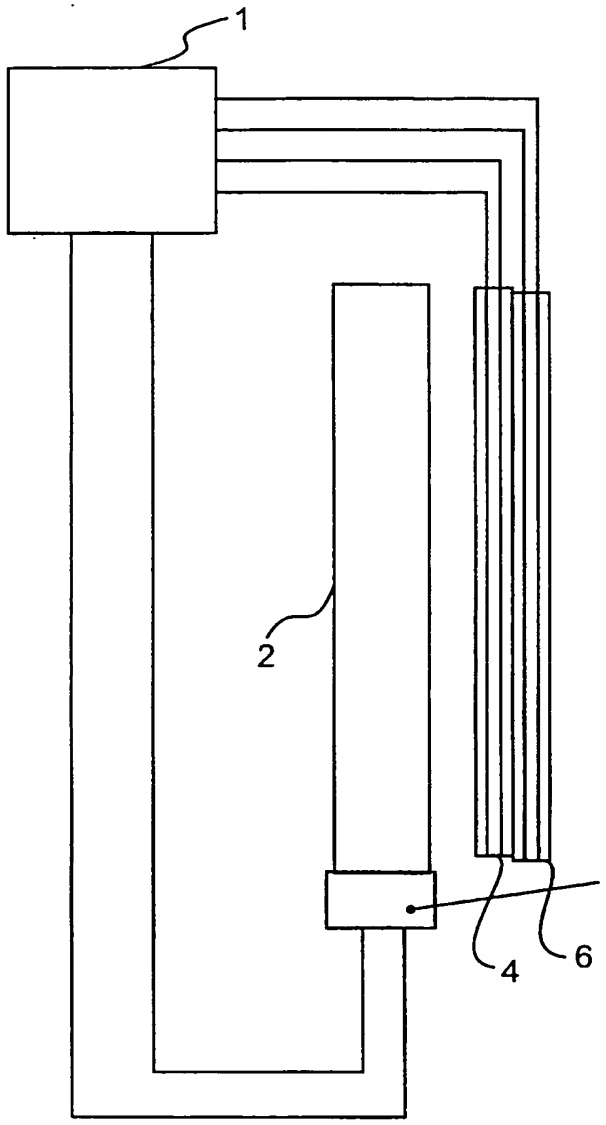


FIG. 1

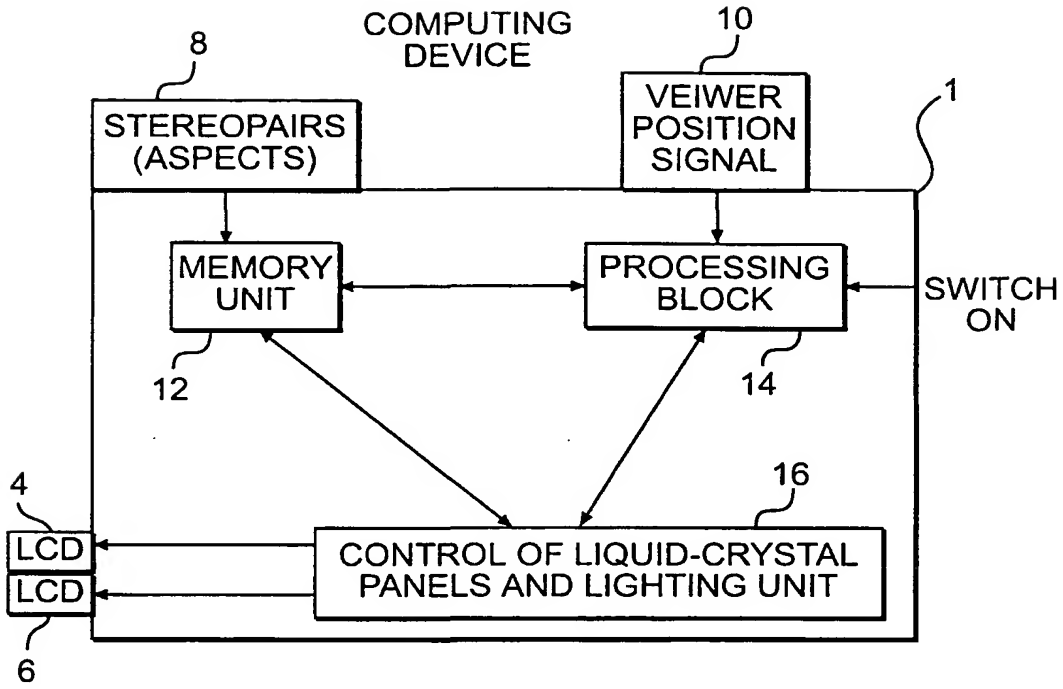

COMPUTING DEVICE
8
10
STEREOPAIRS (ASPECTS)
VEIWER POSITION SIGNAL
1
MEMORY UNIT
PROCESSING BLOCK
SWITCH ON
12
14
4
16
LCD
LCD
CONTROL OF LIQUID-CRYSTAL PANELS AND LIGHTING UNIT
6

FIG. 2

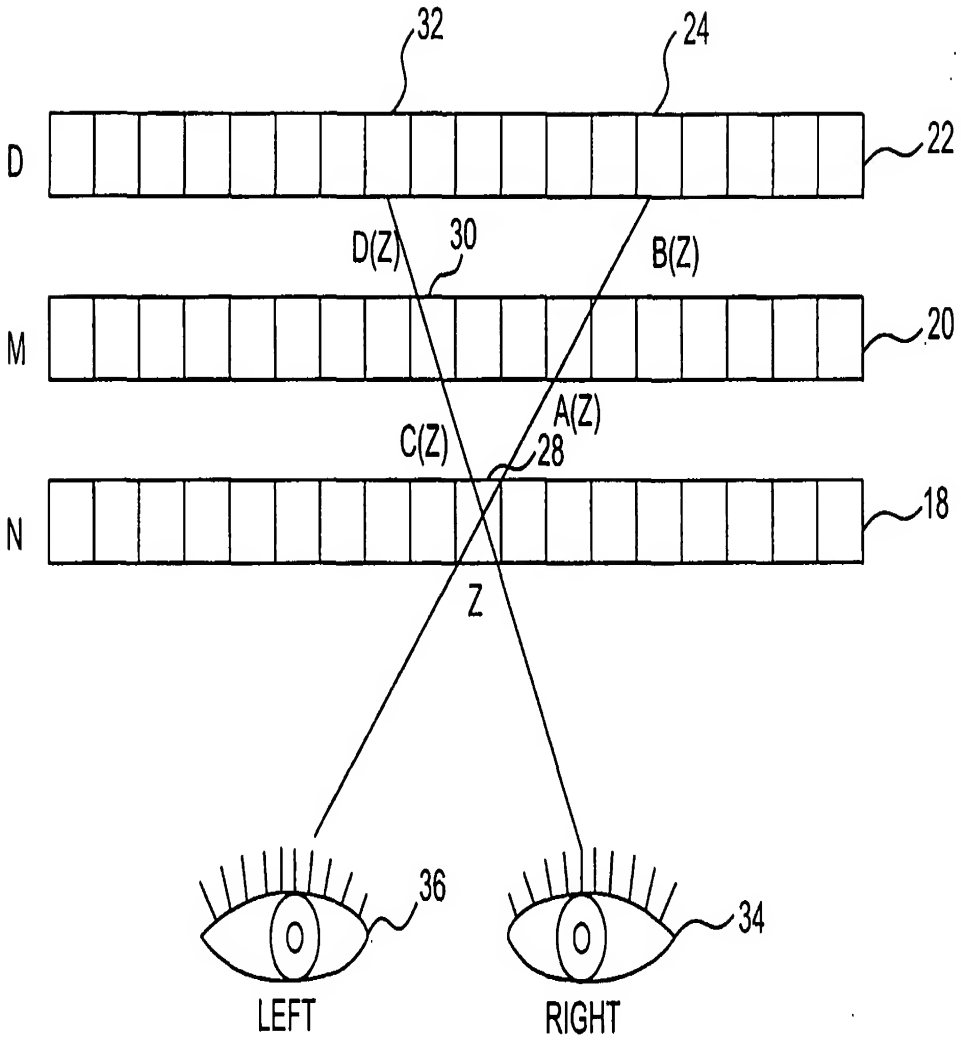
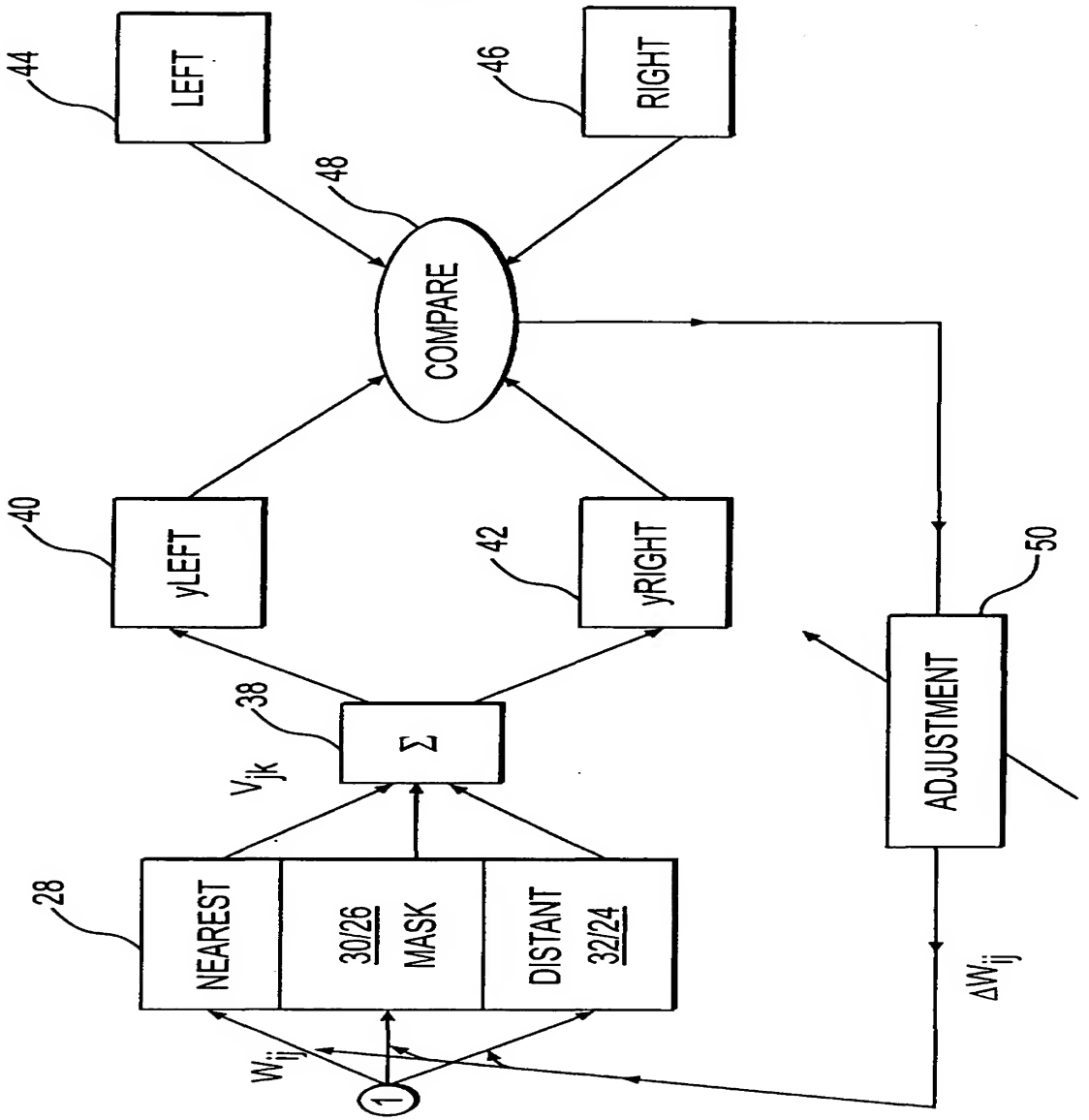


FIG. 3


LEFT
RIGHT
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MASK
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32/24
W_{ij}
1
ADJUSTMENT
50
ΔW_{ij}

FIG. 4

INTERNATIONAL SEARCH REPORT

Intern ıal Application No
PCT/US 00/30683

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N13/04 H04N13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 973 831 A (KLEINBERGER ILAN D ET AL) 26 October 1999 (1999-10-26) column 32, line 30 -column 34, line 30; figures 18-21	1-3,5,6

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 January 2001	12/01/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Paepe, W

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

...ormation on patent family members

Intern ial Application No
PCT/US 00/30683

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5973831 A	26-10-1999	AU 1703097 A	11-08-1997
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